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PTO/SB/05 (12/97)
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UTILITY PATENT APPLICATION TRANSMITTAL

(Only for new nonprovisional applications under 37 CFR 1 53(b))

Attorney Docket No.	TI-23103
First Named Inventor or Application Identifier	Mahalingam Nandakumar
Title	Dual-Counterdoped Channel Field Effect Transistor and Method
Express Mail Label No.	EL255677255US

APPLICATION ELEMENTS

See MPEP Chapter 600 concerning utility patent application contents

ADDRESS TO: Assistant Commissioner for Patents, Box Patent Application, Washington, DC 20231

1. [X] Fee Transmittal Form *(e.g., PTO/SB/17)* *(Submit an original, and a duplicate for fee processing)*
2. [X] Specification *[Total Pages 11]* *(preferred arrangement set forth below)*
   - Descriptive title of the Invention
   - Cross References to Related Applications
   - Statement Regarding Fed sponsored R&D
   - Reference to Microfiche Appendix
   - Background of the Invention
   - Brief Summary of the Invention
   - Brief Description of the Drawings *(if filed)*
   - Detailed Description
   - Claim(s)
   - Abstract of the Disclosure
3. [X] Drawing(s) *(35 USC d113)* *[Total Sheets 2]*
4. Oath or Declaration *[Total Pages 2]*
   - a. [X] Newly Executed (original or copy)
   - b. [ ] Copy from a prior application (37 CFR §1.63(d)) *(for continuation/divisional with Box 17 completed)*

   [Note Box 5 below]

   - i. [ ] DELETION OF INVENTOR(S) Signed statement attached deleting inventor(s) named in the prior application, see 37 CFR §1.63(d)(2) and 1.33(b).
5. [ ] Incorporation By Reference *(useable if Box 4b is checked)* The entire disclosure of the prior application, from which a copy of the oath or declaration is supplied under Box 4b, is considered as being part of the disclosure of the accompanying application and is hereby incorporated by reference therein.
6. [ ] Microfiche Computer Program *(Appendix)*
7. Nucleotide and/or Amino Acid Sequence Submission *(if applicable, all necessary)*
   - a. [ ] Computer Readable Copy
   - b. [ ] Paper Copy (identical to computer copy)
   - c. [ ] Statement verifying identical of above copies

ACCOMPANYING APPLICATION PARTS

8. [X] Assignment Papers (cover sheet & Documents(s))
9. [ ] 37 CFR §3.73(b) Statement *(when there is an assignee)* [X] Power of Attorney
10. [ ] English Translation Document *(if applicable)*
11. [ ] Information Disclosure Statement (IDS)/PTO-1449 [ ] Copies of IDS Citations
12. [X] Preliminary Amendment
13. [X] Return Receipt Postcard (MPEP 503) *(Should be specifically itemized)*
14. [ ] *Small Entity Statement(s) [ ] Statement filed in prior application Status still proper and desired *(PTO/SB/09-12)*
15. [ ] Certified Copy of Priority Document(s) *if foreign priority is claimed)*
16. [ ] Other:

*A new statement is required to be entitled to pay small entity fees, except where one has been filed in a prior application and is being relied upon.

17. If a CONTINUING APPLICATION, *check appropriate box and supply the requisite information below and in a preliminary amendment:*

☐ Continuation ☐ Divisional ☐ Continuation-in-part (CIP) of prior application No: /

Prior application information: ***Examiner*** ***Group / Art Unit:***

18. CORRESPONDENCE ADDRESS

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Signature		*Date*	2/18/99

IN THE UNITED STATES PATENT AND TRADEMARK OFFICE

In Re the Application of: Docket No.: TI-23103

Mahalingam Nandakumar, et al. Examiner: To Be Determined

Serial No.: To Be Determined Art Unit: To Be Determined

Filed: 2/18/99

For: Dual-Counterdoped Channel Field Effect Transistor and Method

PRELIMINARY AMENDMENT

Assist. Commissioner for Patents
Washington, DC 20231

"EXPRESS MAILING" Mailing Label No. **EL255677255US**,
Date of Deposit: **February 18, 1999**.

Dear Sir:

Please amend the specification by inserting before the first line the sentence:

This application claims priority under 35 USC § 119 (e) (1) of provisional application number 60/075,813, filed 2/24/98.

Respectfully submitted,

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DUAL-COUNTERDOPED CHANNEL FIELD EFFECT TRANSISTOR AND METHOD

TECHNICAL FIELD OF THE INVENTION

This invention relates generally to semiconductor devices and more particularly to a dual-counterdoped channel field effect transistor and method.

BACKGROUND OF THE INVENTION

In the art of field effect transistor (FET) design, it is desirable to minimize the leakage (off-state) current while maximizing the drive (on-state) current of the FET. One known method for achieving this result is to surround the source and drain regions with pockets or halos of doping, while counterdoping the channel region. This practice minimizes the short-channel effects that negatively affect the performance of small-scale FETs. However, to achieve this result, a high level of doping is necessary in the pockets around the source and drain regions to counteract the effect of the counterdoping in the channel. The high level of doping results in high source and drain capacitances, thus decreasing the switching speed of the FET.

SUMMARY OF THE INVENTION

Therefore, a need has arisen for an improved field effect transistor that addresses the disadvantages and deficiencies of the prior art.

A field effect transistor with a dual-counterdoped channel in accordance with the present invention is disclosed. The transistor features a channel comprising first and second doped regions. The second doped region underlies the first doped region. A source and drain are formed adjacent to the channel. In one embodiment of the present invention, the first doped region comprises an arsenic dopant, while the second doped region comprises a phosphorus dopant.

A technical advantage is that subsurface channel layer is formed in the central portion of the channel that has greater charge-carrier mobility than conventional surface channels, thus allowing a lower dopant concentration to be used in the subsurface channel layer without negatively affecting transistor performance. Another technical advantage is that the lower subsurface channel doping allows lower source/drain pocket doping, thus reducing the capacitance and response time of the transistor. Yet another technical advantage is that the channel length of the transistor may be decreased without increasing the capacitance and response time of the transistor to unacceptable levels. Yet another technical advantage is that chip size may be reduced, thereby increasing yield from a single wafer and decreasing chip cost.

BRIEF DESCRIPTION OF THE DRAWINGS

For a more complete understanding of the present invention and for further features and advantages thereof, reference is now made to the following description taken in conjunction with the accompanying drawings, in which:

FIGURES 1A through 1E are side views of a semiconductor device in various stages of fabrication in accordance with one embodiment of the present invention.

DETAILED DESCRIPTION OF THE INVENTION

FIGURES 1A through 1E illustrate a method for forming a semiconductor device having a dual-counterdoped channel field effect transistor in accordance with the present invention.

Referring to FIGURE 1A, a cross section of a semiconductor device 10 during fabrication is shown. Semiconductor device 10 includes a substrate 12 which comprises silicon, silicon on insulator (SOI), or any other appropriate substrate for semiconductor fabrication. A plurality of doped wells 14, 16 and 18 are formed in substrate 12 using well-known techniques. For example, well 16 may be a p-type well, while wells 14 and 18 may be n-type wells. For purposes of illustration, well 16 will be assumed to be a p-type well in the following description. However, it will be understood that well 16 may be an n-type well, with the appropriate substitution of n-type dopants for p-type dopants (and vice versa) throughout the following description.

Wells 14, 16 and 18 are separated by isolation trenches 20, which may be filled with an insulating material such as silicon dioxide in accordance with known isolation techniques. Alternatively, other forms of isolation, such as LOCOS isolation, may be used. An insulating layer 22 covers the surface of substrate 12. Insulating layer 22 may also comprise silicon dioxide.

Referring to FIGURE 1B, a channel region 24 of substrate 12 is counterdoped with n-type dopants in accordance with the present invention. One ion implantation is performed to form a subsurface doped layer 26. In this example, the dopant used for this implantation is phosphorus. Another ion implantation is performed to form a surface doped layer 28. In this example, the dopant used for this implantation is arsenic. Alternatively,

surface layer 28 may not be doped at all. Additional implementation of p-type dopants may also be performed to adjust threshold voltage and for punch-through control.

Referring to FIGURE 1C, a gate material such as polysilicon is deposited and patterned to form gate 30. This step may be performed in accordance with well known gate formation techniques.

Referring to FIGURE 1D, source/drain pockets 32 are formed using ion implantation. In this example, source/drain pockets 32 are implanted with a p-type material such as indium. Preferably, a heavy element such as indium (for p-doped pockets) or arsenic or antimony (for n-doped pockets) is used to form source/drain pockets 32. Heavy elements are preferred because of their relatively narrow and steep doping profile. In other words, these heavy dopants create a sharp transition in dopant concentration between source/drain pockets 32 and substrate 12. This sharp transition in dopant concentration reduces the deleterious short-channel effects exhibited by semiconductor device 10. Alternatively, lighter dopants such as boron (BF_2) and phosphorus may be used.

Referring to FIGURE 1E, source/drain regions 34 are formed using ion implantation. In this example, source/drain pockets 32 are implanted with an n-type material such as arsenic. Although source/drain pockets 32 are shown extending around source/drain region 34 and adjoining isolation trenches 20, it will be understood that source/drain pockets 32 may extend only along the inside portion of source/drain regions 34 adjoining the channel. Alternatively, a deeper source/drain implant may be performed to extend source/drain regions 34 over the bottom portion of source/drain pockets 32. Either one of these well-known methods reduces the capacitance of the transistor, thereby improving transistor performance.

The transistor formed by the foregoing steps exhibits superior performance over previous transistors. Specifically, this transistor utilizes subsurface doped layer 26 as the primary conduction channel between source/drain regions 34. Subsurface doped layer 26 has greater charge-carrier mobility than conventional surface channels. A desired channel conductivity may therefore be achieved with a lower n-type dopant concentration in subsurface doped layer 26. Since source/drain pockets 32 must be sufficiently p-doped to overcome the counterdoping of channel region 24, the lower n-type dopant concentration allows a lower p-type dopant concentration to be used in source/drain pockets 32. The reduced source/drain pocket doping reduces the capacitance and the response time of the transistor. Channel 24 may therefore be shortened, with a corresponding increase in source/drain pocket dopant concentration, without increasing the capacitance and response time of the transistor to unacceptable levels. The overall size of semiconductor device 10 is thereby reduced, increasing the yield from a single wafer and decreasing the cost of a chip. Alternatively, the above-described method could be used to reduce short-channel effects and improve transistor performance for a given pocket doping level.

While the invention has been particularly shown and described by the foregoing detailed description, it will be understood by those skilled in the art that various other changes in form and detail may be made without departing from the spirit and scope of the invention.

WHAT IS CLAIMED IS:

1. A field effect transistor comprising:

a channel having a first doped region and a second doped region underlying the first doped region;

a source adjacent to the channel; and

a drain adjacent to the channel.

2. The field effect transistor of Claim 1, wherein the first doped region comprises a first concentration of a dopant, and wherein the second doped region comprises a second concentration of the dopant, the first concentration being greater than the second concentration.

3. The field effect transistor of Claim 2, wherein the dopant comprises an n-type dopant.

4. The field effect transistor of Claim 1, wherein the first doped region comprises a first dopant, and wherein the second doped region comprises a second dopant different from the first dopant.

5. The field effect transistor of Claim 4, wherein the first dopant comprises arsenic, and wherein the second dopant comprises phosphorus.

6. The field effect transistor of Claim 1, further comprising a first pocket surrounding the source and a second pocket surrounding the drain, the first and second pockets each having a higher dopant concentration than the source and drain regions.

7. A semiconductor device comprising a plurality of field effect transistors, at least one of the field effect transistors having a channel comprising a subsurface doped layer, the field effect transistor further having a source adjacent to the channel, a drain adjacent to the channel and a gate overlying the channel.

8. The semiconductor device of Claim 7, wherein the channel of the field effect transistor further comprises a surface doped layer overlying the subsurface doped layer.

9. The semiconductor device of Claim 8, wherein the surface doped layer comprises a first concentration of a dopant, and wherein the subsurface doped layer comprises a second concentration of the dopant, the first concentration being greater than the second concentration.

10. The semiconductor device of Claim 9, wherein the dopant comprises an n-type dopant.

11. The semiconductor device of Claim 8, wherein the surface doped layer comprises a first dopant, and wherein the subsurface doped layer comprises a second dopant different from the first dopant.

12. The semiconductor device of Claim 11, wherein the first dopant comprises arsenic, and wherein the second dopant comprises phosphorus.

13. The semiconductor device of Claim 7, further comprising a first doped pocket surrounding the source and a second doped pocket surrounding the drain, the first and second pockets each having a higher dopant concentration than the source and drain regions.

14. A method for forming a field effect transistor, comprising the steps of:

implanting a first dopant in a subsurface channel region;

forming a gate over the subsurface channel region; and

implanting a second dopant in a source/drain region adjacent to the subsurface channel region.

15. The method of Claim 14, further comprising the step of implanting a third dopant in a surface channel region overlying the subsurface channel region.

16. The method of Claim 14, further comprising the step of implanting a fourth dopant in a pocket surrounding the source/drain region.

17. The method of Claim 15, wherein the first dopant comprises phosphorus, and wherein the second dopant comprises a p-type dopant, and wherein the third dopant comprises arsenic.

DUAL-COUNTERDOPED CHANNEL FIELD EFFECT TRANSISTOR AND METHOD

ABSTRACT OF THE DISCLOSURE

A field effect transistor with a dual-counterdoped channel is disclosed. The transistor features a channel comprising a first doped region (28) and a second doped region (26) underlying the first doped region. A source and drain (32) are formed adjacent to the channel. In one embodiment of the present invention, the first doped region (28) is doped with arsenic, while the second doped region (26) is doped with phosphorus. The high charge-carrier mobility of the subsurface channel layer (28) allowing a lower channel dopant concentration to be used, which in turn allows lower source/drain pocket doping. This reduces the capacitance and response time of the transistor.

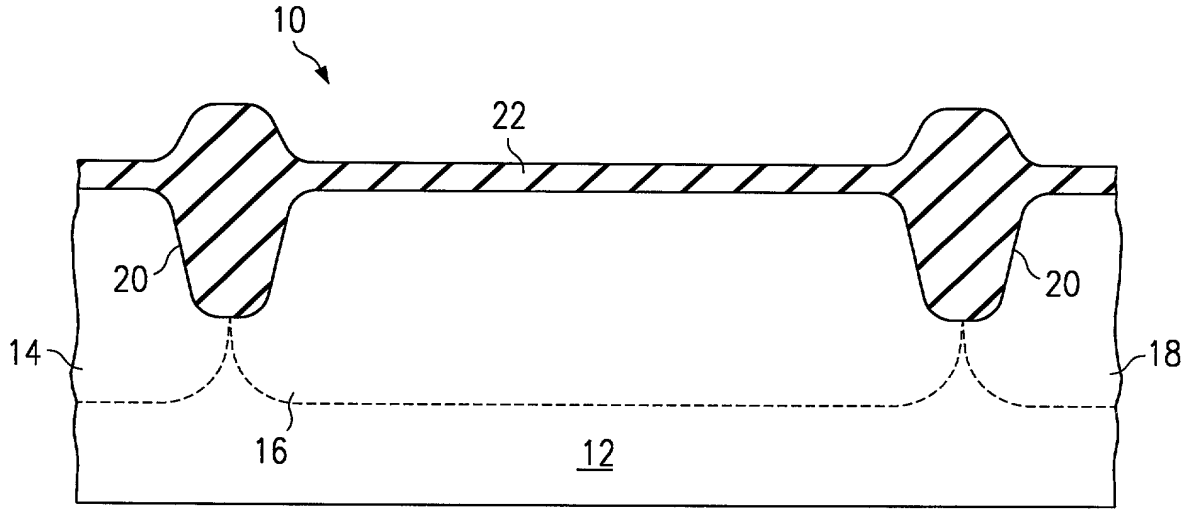

FIG. 1A

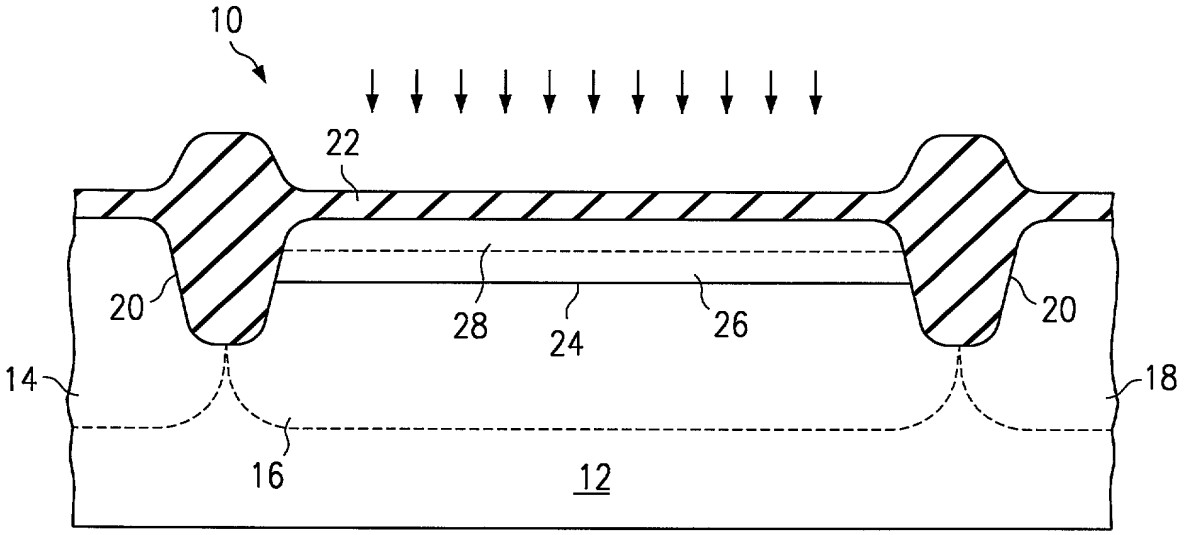

FIG. 1B

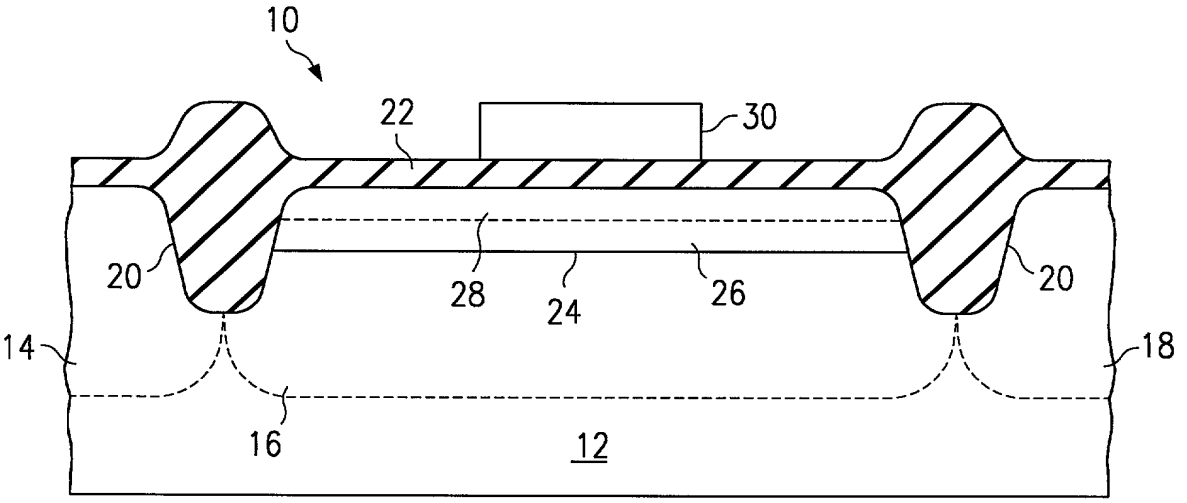

FIG. 1C

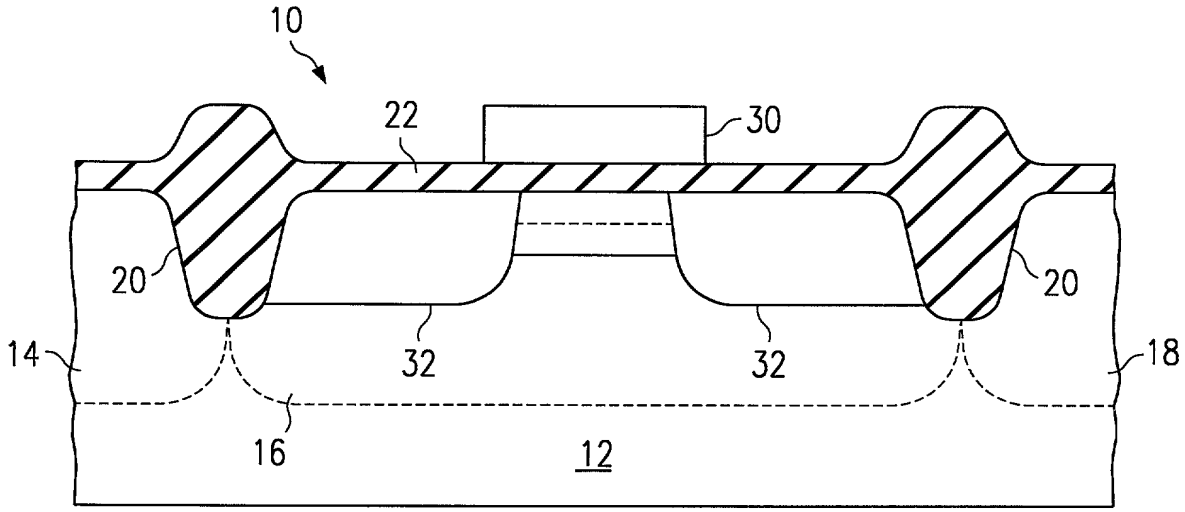

FIG. 1D

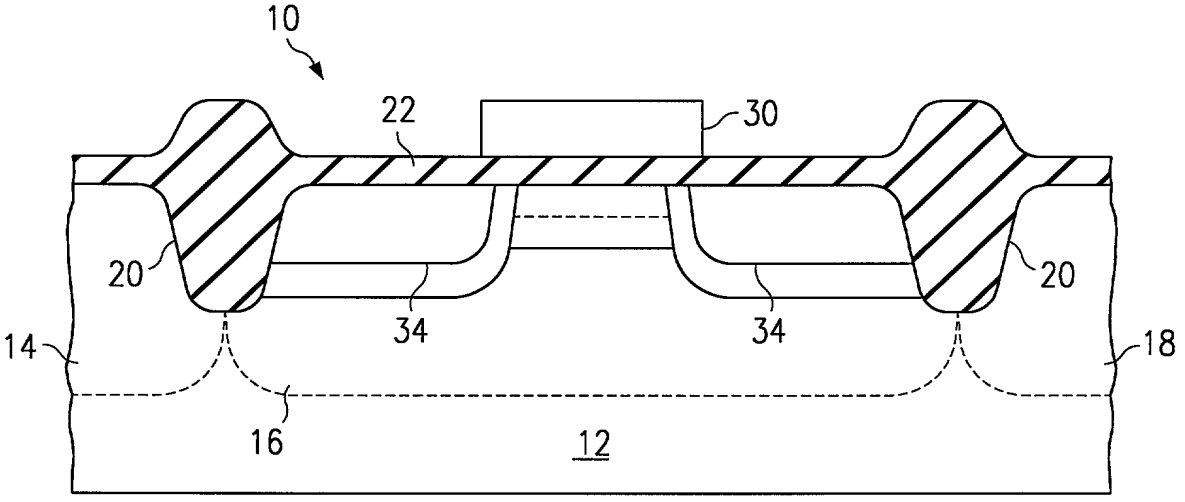

FIG. 1E

APPLICATION FOR UNITED STATES PATENT

Declaration and Power of Attorney

As a below named inventor, I hereby declare that my residence, post office address and citizenship are as stated below next to my name; that I believe that I am the original, first and sole inventor (if only one name is listed below) or an original, first and joint inventor (if plural names are listed below) of the subject matter which is claimed and for which a patent is sought on the invention entitled as set forth below, which is described in the attached specification; that I have reviewed and understand the contents of such specification, including the claims, as amended by any amendment specifically referred to in the oath or declaration; that no application for patent or inventor's certificate on this invention has been filed by me or my legal representatives or assigns in any country foreign to the United States of America; and that I acknowledge the duty to disclose to the U.S. Patent and Trademark Office all information known to me to be material to patentability as defined in 37 C.F.R. § 1.56.

I hereby declare that all statements made herein of my own knowledge are true and that all statements made on information and belief are believed to be true, and further that these statements were made with the knowledge that willful false statements and the like so made are punishable by fine or imprisonment, or both, under section 1001 of Title 18 of the United States Code, and that such willful false statements may jeopardize the validity of the application or any patent issuing thereon.

TITLE OF INVENTION:

DUAL-COUNTERDOPED CHANNEL FIELD EFFECT TRANSISTOR AND METHOD

I hereby appoint the following attorneys to prosecute this application and transact all business in the Patent and Trademark Office connected therewith:

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Date:	3/20/98